A Real-Time Coastal Ocean Prediction Experiment

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Introduction: A test of the rapid relocatability of NRL coastal ocean prediction systems was carried out during the Maritime Rapid Environmental Assessment 2004 (MREA04) Trial in the Portuguese coastal waters. The ocean circulation capability was first demonstrated in response to the oil spill from the tanker *Prestige* off the northwest coast of Spain and in support of Operation Iraqi Freedom. A nested Navy Coastal Ocean Model (NCOM) assimilated satellite altimeter sea surface height anomalies, sea surface temperatures, and in situ CTD temperature and salinity profiles collected onboard the NATO Undersea Research Center's (NURC) R/V *Alliance*. The Distributed Integrated Ocean Prediction System (DIOPS) provided real-time predictions of nearshore waves, tides, currents, and surf conditions.

Ocean Circulation Model: An experimental real-time ocean nowcast/forecast system[1] was rapidly developed for the Portuguese coastal waters for the MREA04 Trial. The area of coverage extended from 8°W to 11°W and from 36°N to 40°N. The NCOM ocean model consisted of a 4-km resolution host grid, with a 1-km nested grid covering the central coastal region of the host grid. A 40-layer hybrid vertical grid was used with sigma layers from the surface down to 140 m and fixed-depth layers from 140 m to the bottom. Bathymetry was obtained by combining data from several sources at spatial resolutions ranging from 2 min to 6 s. Figure 1 shows the NCOM grid and bathymetry used during MREA04.

Initial and open-boundary conditions of sea surface elevation, temperature, salinity, and currents were provided by the 1/8th-deg global NCOM that is being run in real time at NRL. Tidal forcing was provided by superimposing tidal elevation and transports on the (nontidal) boundary conditions from global NCOM, providing tidal potential forcing over the interior of the model domain. The tidal boundary data were obtained from the global tidal database developed at Oregon State University.[2] Freshwater discharge was provided for the Mondego, Tagus, Tamega, Sado, and Odelouca Rivers. Atmospheric forcing consisted of hourly fields of surface air pressure, wind stress, solar radiation, and surface heat flux from the 27-km resolution Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS™) Europe analysis/forecast model.

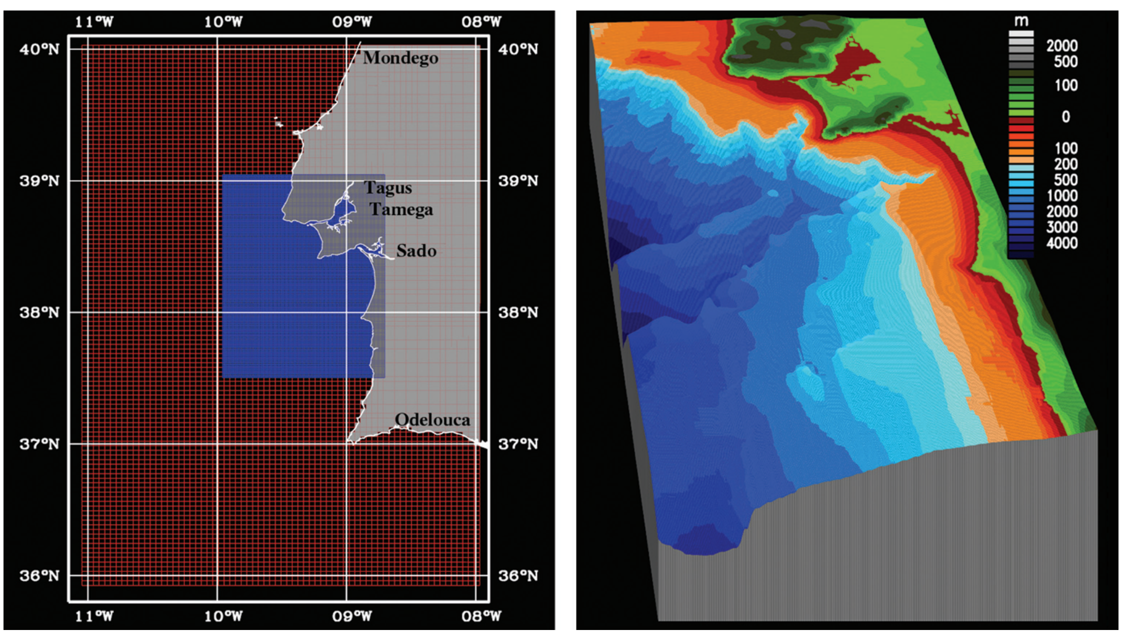

FIGURE 1
Left: Nested NCOM grid for MREA04 Trial. Outer grid (red) has horizontal 4-km resolution inner grid (blue) has 1-km resolution. River discharge locations are annotated. Right: 3D depiction of model topography (m) for 1-km NCOM nest. Note canyon feature that extends close to the coast.

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The MREA04 NCOM system provided daily 72-h forecasts of sea level variation and 3D ocean currents, temperature, and salinity fields during the experiment period of 27 March to 18 April 2004. NCOM assimilated temperature/salinity analyses generated from satellite altimeter (GFO, JASON-1, ERS-2) sea surface height anomaly and satellite-derived sea surface temperature. In addition, the nested NCOM system assimilated CTD temperature/salinity profiles collected by the R/V *Alliance* during the MREA04 cruise. A 3D temperature salinity estimation was produced from satellite data using the Modular Ocean Data Assimilation System.[3] The CTD profiles were combined with satellite estimates using an optimum interpolation scheme to produce the analyses. Model sound speed compared well to observations. NCOM output was used by NURC in a prototype surface drift prediction using linear and nonlinear hyper-ensemble statistics on atmospheric and ocean models. Figure 2 (top) depicts a 72-h forecast of surface ocean currents overlaid on sea surface temperature for 10 April 2004. Figure 2 (bottom) shows the different salinity structure obtained when CTD data are assimilated into the NCOM model.

Nearshore Modeling System: DIOPS, a wave, tide, and surf prediction system[4] was run aboard the R/V *Alliance* during the MREA04 Trial during the period 28 March – 11 April 2004. A triple nested SWAN wave model forecast was initialized from wave spectra provided by the Fleet Numerical Meteorology and Oceanography Center. The PCTides tide

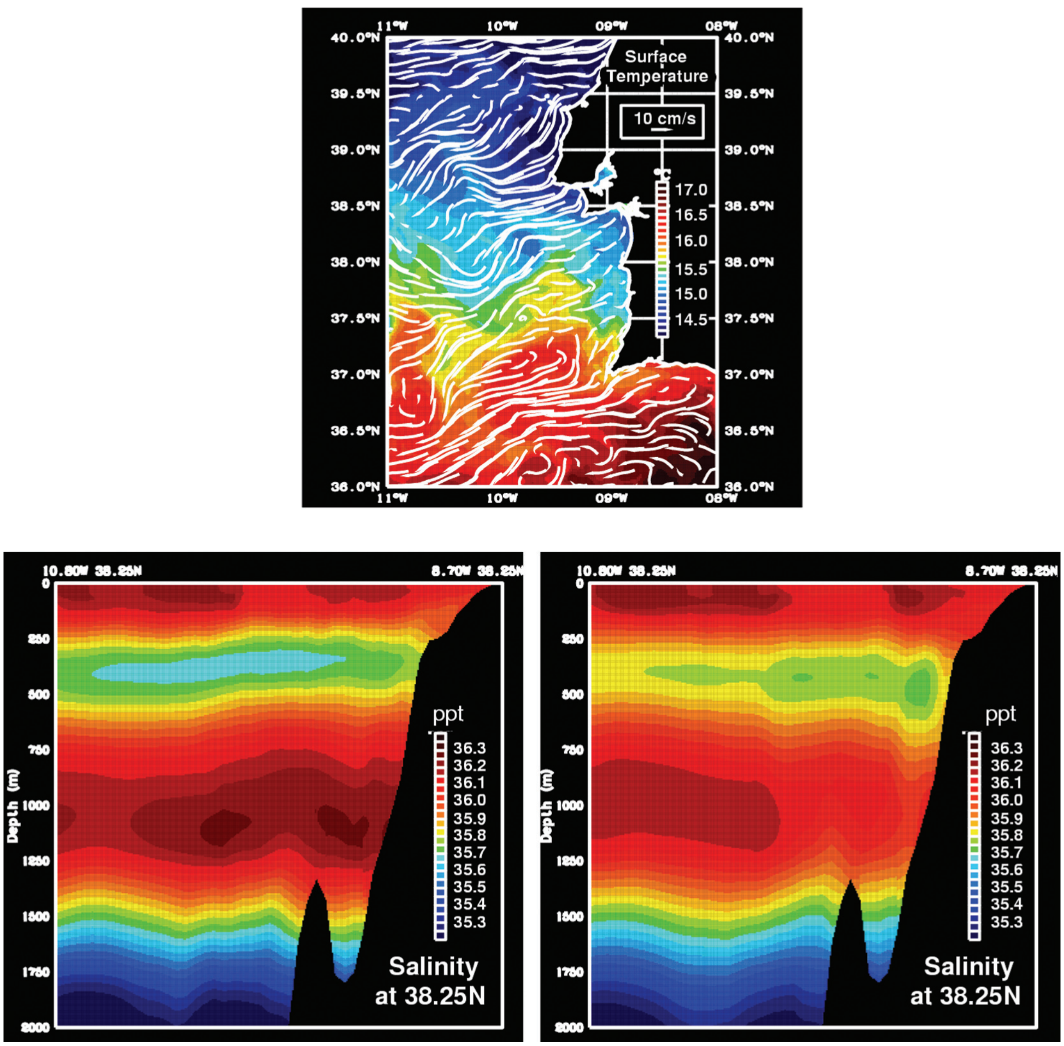

FIGURE 2
Top: NCOM surface analysis for 10 April 2004. White vectors illustrate surface ocean currents overlaid on sea surface temperatures (°C). Bottom: Vertical slice of salinity (ppt) distribution: (left) CTD profiles are assimilated into model; (right) CTD profiles are not assimilated into model.

model provided 48-h predictions of water levels near Pinheiro da Cruz, Portugal. Both wave and tide predictions were used in nearshore wave models and by international hydrographic survey teams. Figure 3 shows the SWAN nested model grid with resolutions ranging from 20 km (host grid) to 1 km near the coast (inner blue box). The Delft3D modeling system provided 10-m resolution nearshore wave and circulation predictions near Pinheiro da Cruz, Portugal. The nearshore modeling was complemented with a beach survey experiment in which video cameras and three NORTEK current meters were deployed. Modeled wave height and direction (Fig. 3) show very good agreement with a Portuguese WaveRider buoy near Sines (97-m water depth). PCTides water levels shown in Fig. 3 compare favorably with in situ data, with tidal amplitude RMS errors of 1 cm and phase errors less than 10 min.

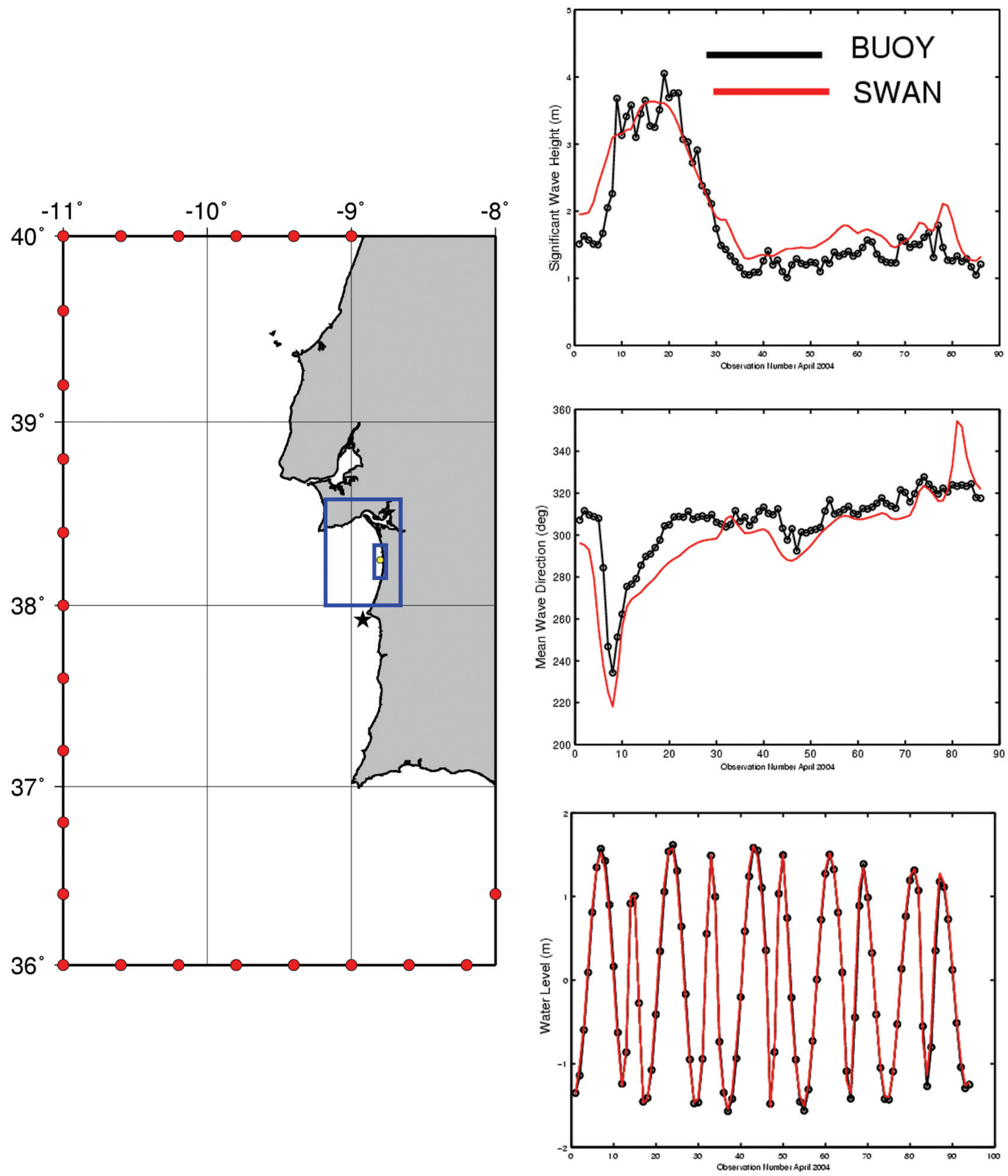

FIGURE 3
Left: Nearshore SWAN wave model domain. Red circles denote locations of directional wave spectra applied to host model grid boundary; blue boxes show inner nests. Black star denotes location of Portuguese wave buoy near Sines: yellow circle denotes location of water level measurements near Pinheiro da Cruz. Right top: Comparison of SWAN wave height at Sines buoy. Black line denotes buoy data, red line denotes SWAN. Middle: Buoy (black) vs SWAN (red) mean wave direction. Bottom: PCTIDES water level (red) vs observed (black) near Pinheiro da Cruz located in center of inner blue box.

Summary: The prototype systems demonstrated during MREA04 show that realistic depictions of ocean circulation, thermal structure, wave, and tidal features are generated with a rapidly relocatable ocean prediction system. Wave height and direction show very good agreement with observations. Water levels from PCTIDES showed excellent agreement with observation. These capabilities will allow the U.S. Navy warfighting community to better exploit the marine environment for tactical mission planning and execution.

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